National Aeronautics and Space Administration

Fundamental Aeronautics Program

Supersonics Project

Airport Noise Overview

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2012 Acoustic Technical Working Group
April 11-12, 2012
Cleveland, Ohio

www.nasa.gov

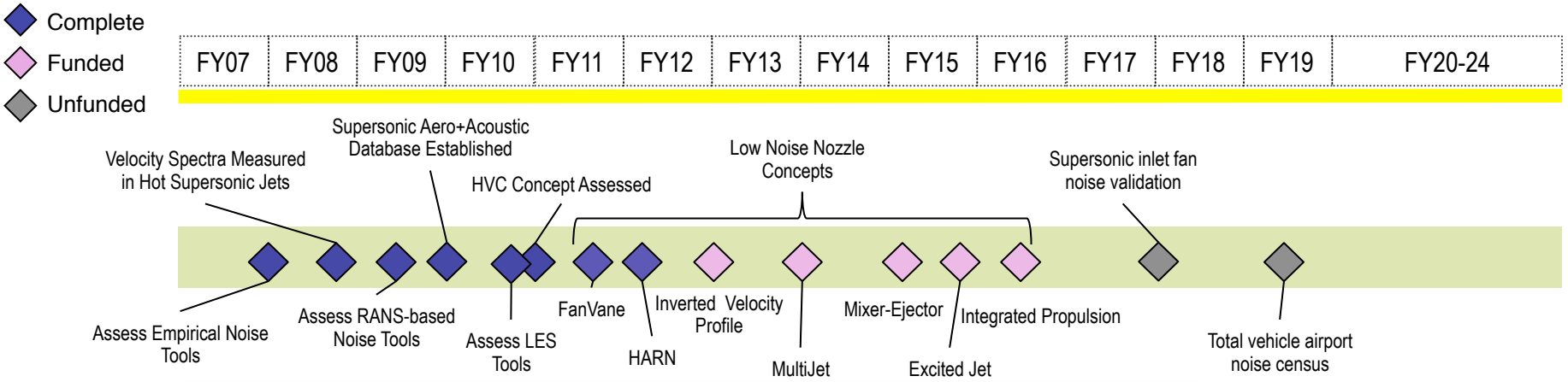
Technical Challenge: Airport Noise

- What are we trying to do?
  - Allow supersonic aircraft to be acoustically acceptable around airports.
  - Develop low noise concepts and the ability to engineer them on low-boom supersonic aircraft.

- What is our approach?
  - Develop and use physics-based codes more and experiments less.
  - Couple both code and concept development to delivery of system-level noise prediction modules

- What are the payoffs if successful?
  - Documented noise reduction technologies with ability to trade design parameters against other design goals.
  - Detailed, physics-based jet noise prediction tools applicable to all stages of aircraft design.

Measuring Progress:
Airport Noise Technical Challenge Milestones



What are the intermediate and final exams to check for success?

- Suite of noise prediction codes at multiple fidelities, validated in component tests.
- Refinement of key low-noise concepts, captured in system-level prediction tools.
- Suite of tools used in multi-objective optimization exercise.

Recent Progress Toward Meeting Technical Challenge

- Tool Development
  - Completed Greens function code for HARN jets.
  - Validated unstructured CFD (RANS & LES) for prediction of nozzle plumes.
- Concept Development
  - Assessed three-stream mixer-ejector variable cycle nozzle concept
  - Assessed inverted velocity profile and fluid shield concept
  - Assessed scalability of plasma actuation for jet turbulence control.
  - Designed low-noise high-aspect ratio nozzles.

NASA External Collaborations

Recently Completed NRA

- **NRA: Prediction and modeling of supersonic jet noise using large-eddy simulation**, Stanford U., U. Illinois Urbana-Champagne, Sanjiva Lele, PI
- **NRA: Supersonic Jet Noise Suppression Using Plasma Actuators: Coupled Experiments, LES and Adjoint-based Optimization**, Ohio State U., U. Illinois Urbana-Champagne, Mo Samimy, PI

Ongoing

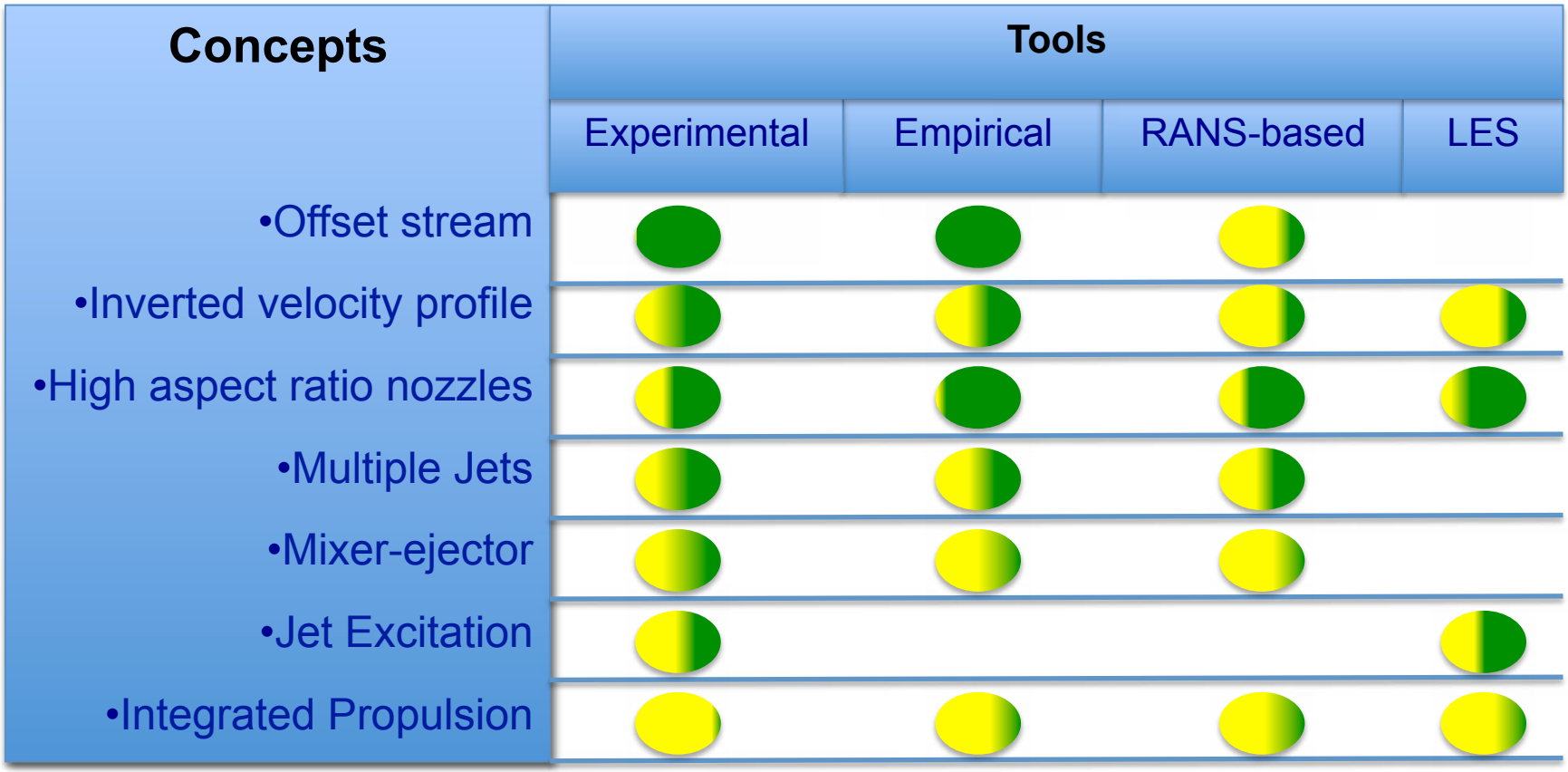
- **NRA: N+2 System Validation**, Lockheed-Martin, Rolls-Royce LibertyWorks, GE Global Research, John Morgenstern, PI
- **SBIR Phase II: LES of Rectangular Nozzles**, CRAFT Tech, Neeraj Sinha, PI.

Other Government Agencies

- **Air Force/Navy/NASA Cooperation on SBIR/STTR** for Jet Noise Research topics
- **Navy/NASA Research Opportunity**: joint funding of 8 awards in jet noise experiments, LES development, and noise reduction

14:20 Thursday—Brenda Henderson

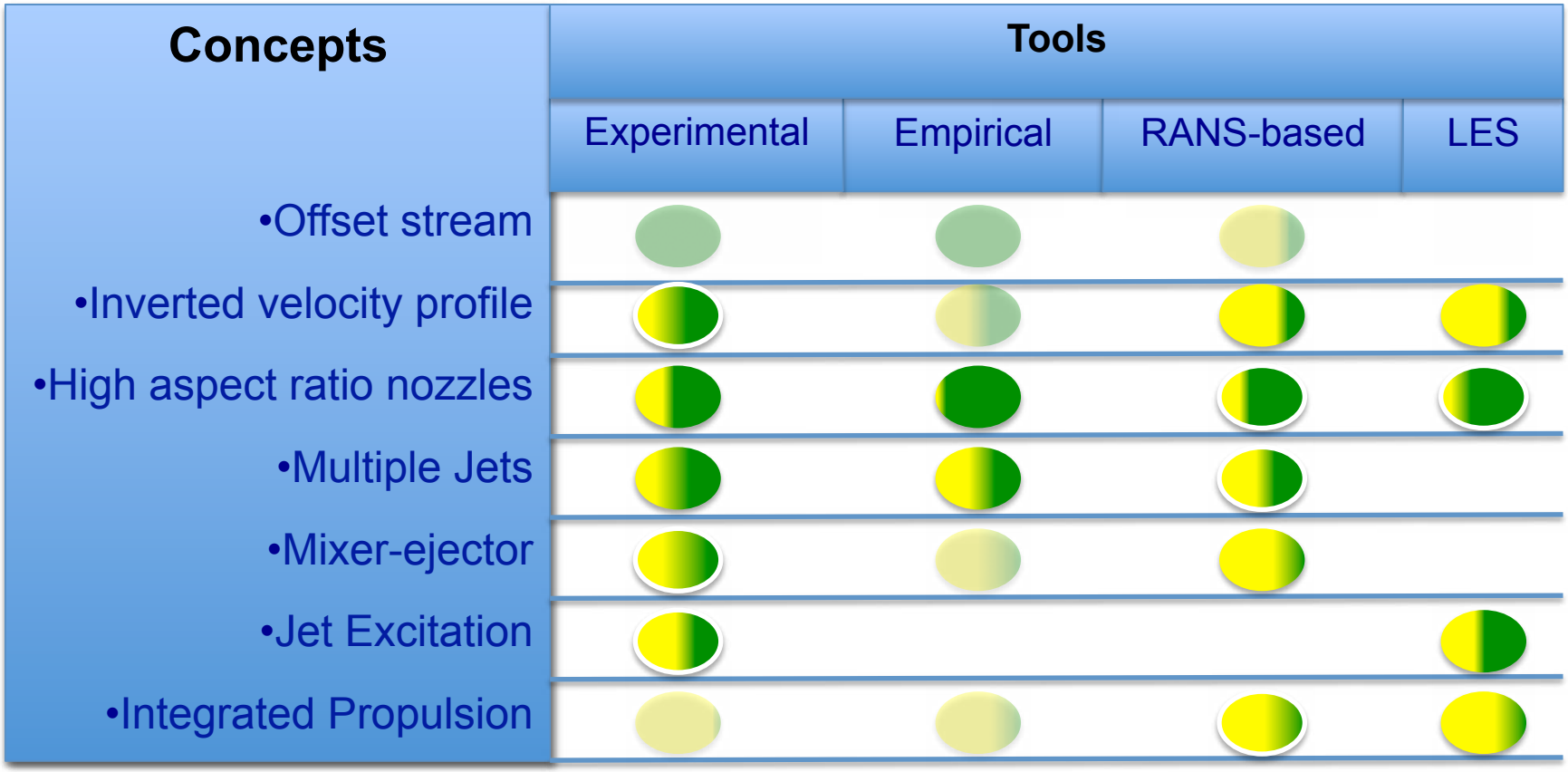
Airport Noise Tech Challenge at a Glance



Tool Development Scale

Needs Development	Ready

Airport Noise Tech Challenge at a Glance

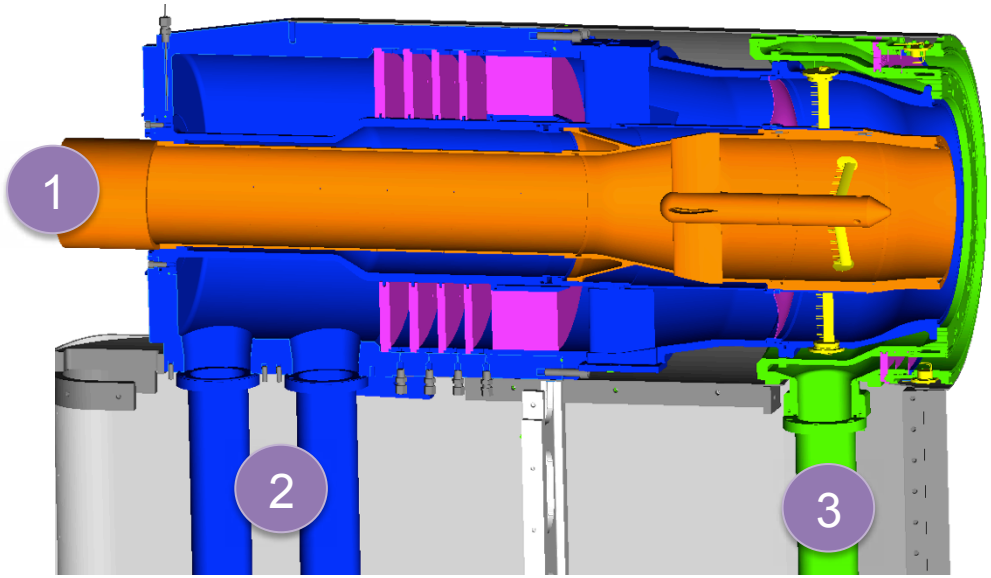


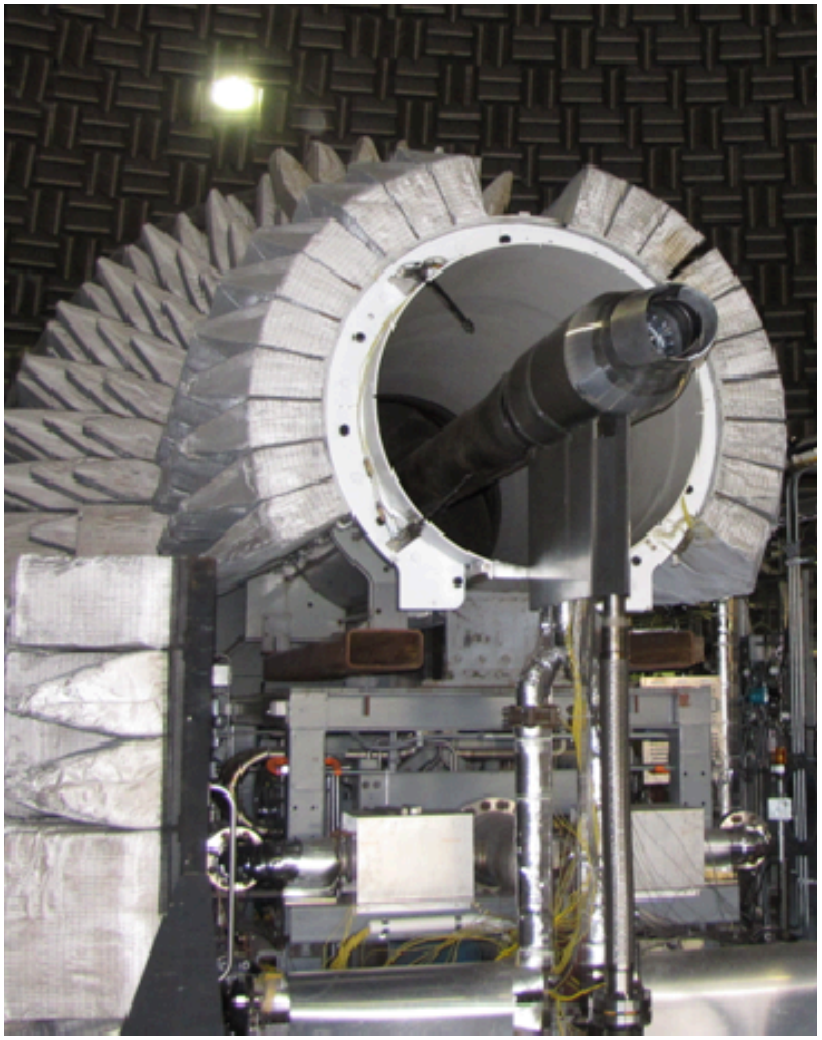
Tool Development Scale

Needs Development	Ready

N+2 System Validation Nozzle Test—NASA

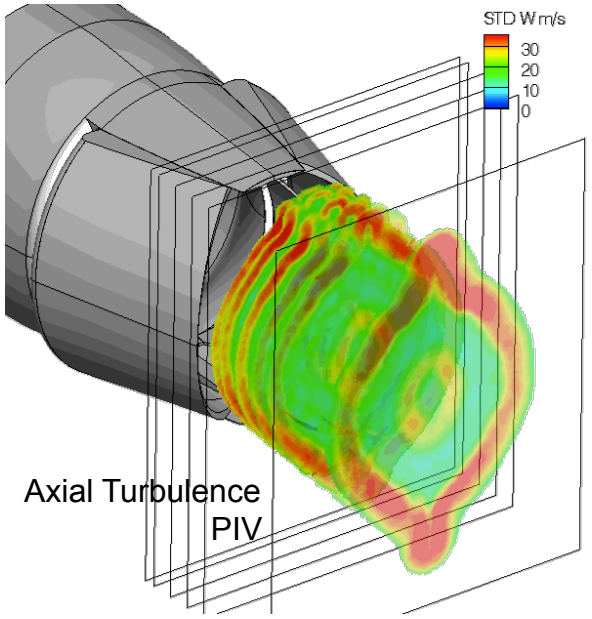
- N+2 Low Noise Nozzle concepts use three-stream engine architecture to achieve highly variable cycles
- Test rig required second fan stream to test concepts for noise
- NASA GRC High Flow Jet Exit Rig modified to provide **quiet** third stream coannular to existing Rig in same outer envelope.

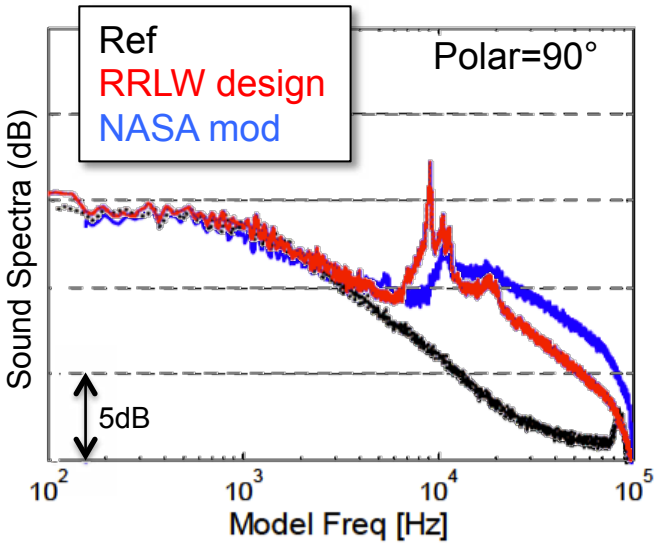




N+2 System Validation Nozzle Test—LM/RRLW

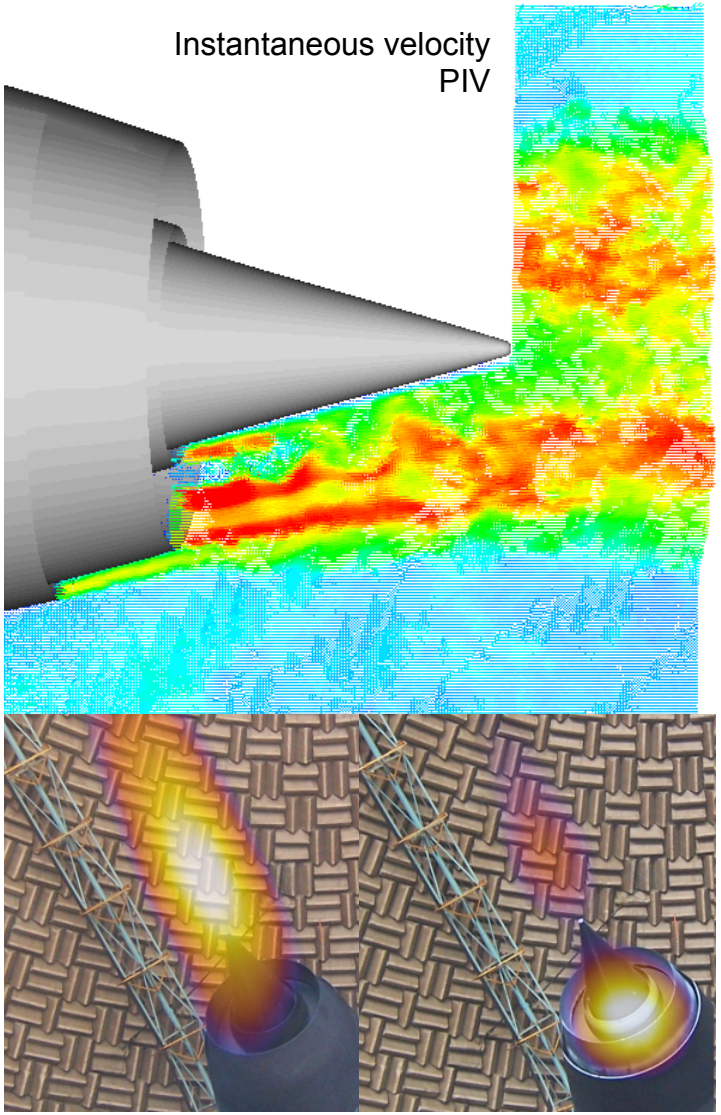
- Three-Stream Mixer-Ejector
  - Lockheed Martin/RR-LibertyWorks contract
  - Model hardware designed and built by RR-LW
  - Three-stream engine test rig provided by NASA
  - Acoustic and flow diagnostic testing performed at NASA
  - Nozzle tested in complicated subsonic ejector mode
- Objective
  - Validate low-noise operation of highly variable nozzle
  - Validate acoustic design tools
- Outcome
  - External jet noise satisfy noise requirements
  - Internal resonances spoil total success
  - Steady RANS CFD did not foreshadow resonances
  - Shows importance of unsteady flow design tools, unstructured grid methods





N+2 System Validation Nozzle Test—LM/GE

- Inverted Velocity Profile w/Fluid Shield
  - Lockheed/GE Global Research contract
  - Model hardware designed and built by GE GR
  - Acoustic and flow diagnostic testing performed at NASA
  - Hot stream inversion in GE model hardware.
- Objective
  - Validate low-noise operation of nozzle with variable cycle conditions, shield orientations
  - Validate acoustic design tools
- Outcome
  - IVP and fluid shield benefit demonstrated when nozzle operating properly expanded.
  - Over-aggressive divergence removed benefit at low-speeds.
  - Steady RANS CFD did not predict divergence issue.
  - Shows need for prediction of noise from separations.

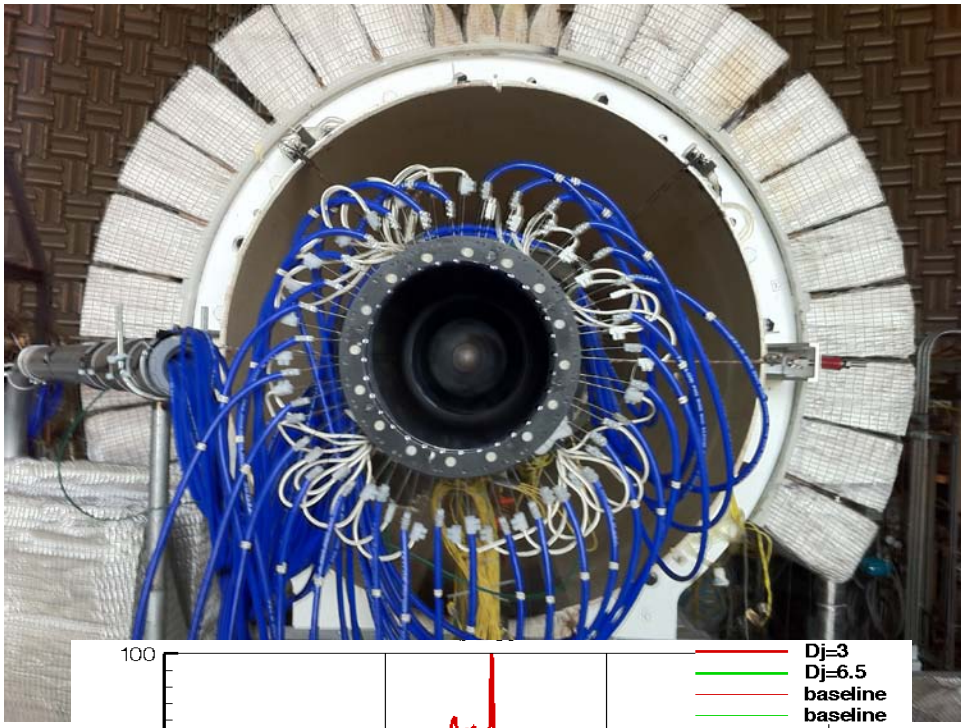


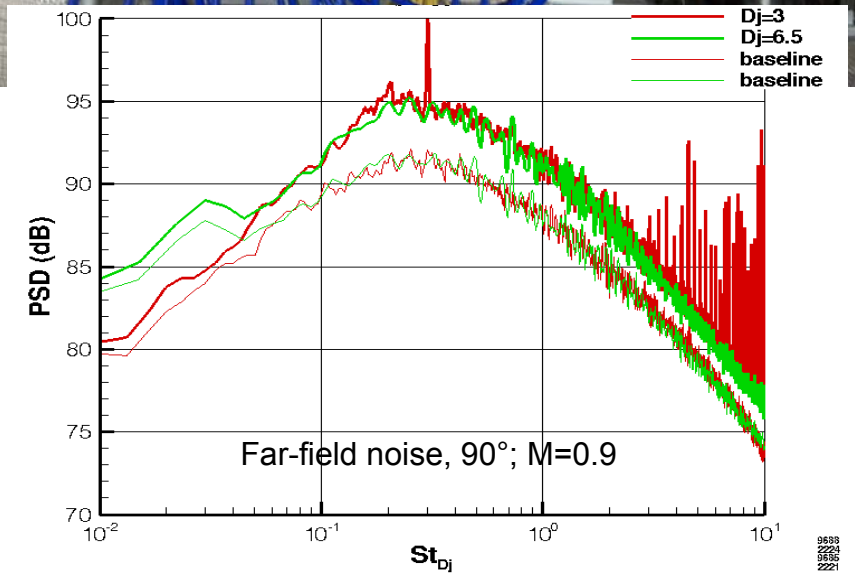
Phased Array Source Distribution

Plasma Actuator for Jet Turbulence Control

- Jet Turbulence Control
  - Control jet turbulence via instabilities
  - NASA/OSU collaboration to develop high-authority actuators for jets
  - LES simulations and adjoint optimization methods to find control strategies for minimum noise
- Objective
  - Replicate jet control in university lab
  - Demonstrate scaling of actuator authority with nozzle size
- Outcome
  - Small-scale results replicated
  - Jet response scales **linearly** with actuator energy over 6:1 range
  - Require more work on optimization strategies for reduction

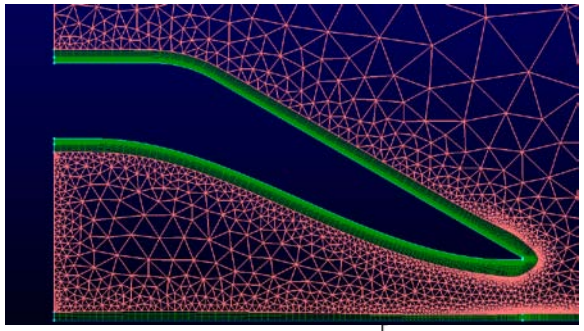
16:10 Thursday—Cliff Brown

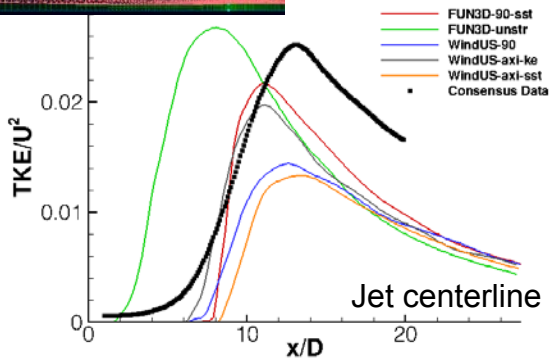


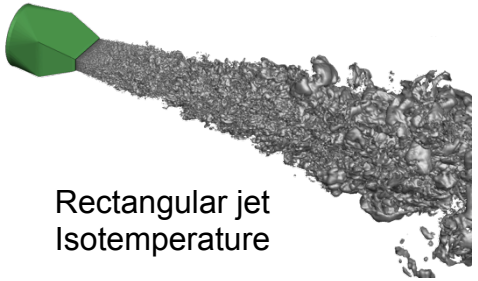


Validation of Unstructured CFD—RANS & LES

- CFD critical to design of realistic exhaust systems
  - Accurate TKE in plume for noise
  - Accurate separation prediction
  - Non-dissipative LES schemes
- Objective
  - Validate total CFD approach—grid, solver, turbulence models—for several codes
  - Adopt best practices to obtain “good enough” solutions
- Outcome
  - New Wind-US unstructured code validated and documented
  - Low-order LES demonstrated and limitations explored

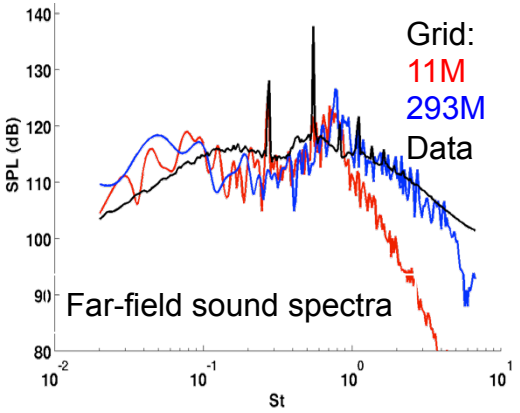






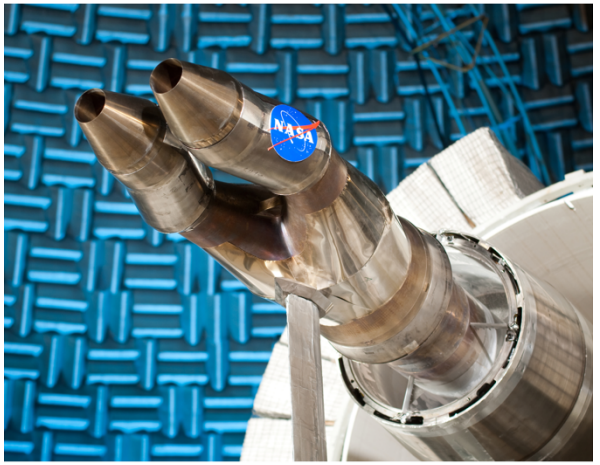
Rectangular jet
Isotemperature

(CharLES code)

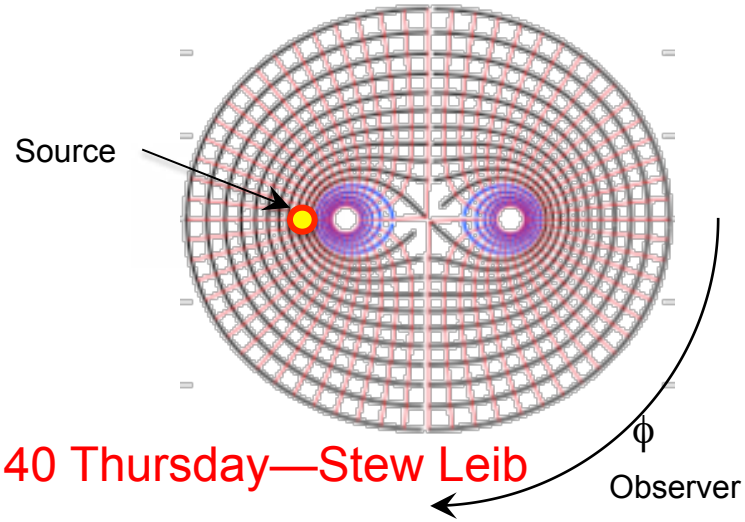


Nonaxisymmetric Greens Functions

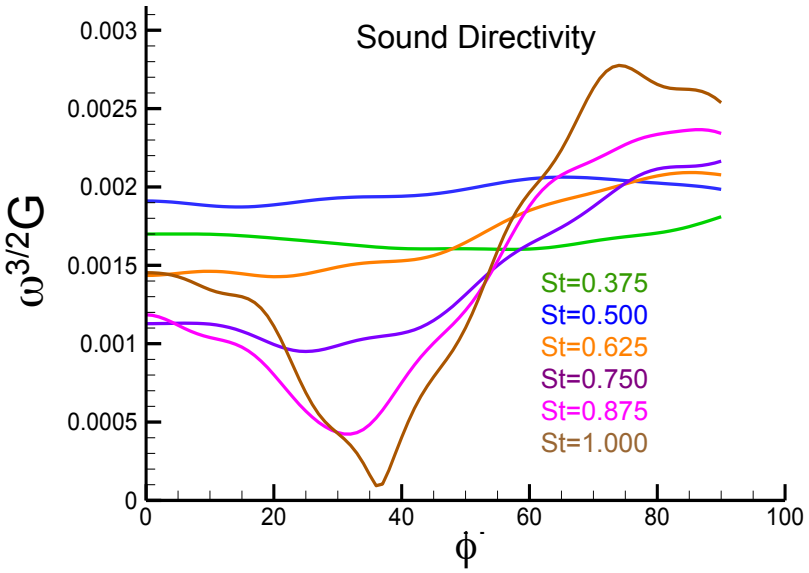
- CFD-based noise prediction
  - Requires Greens function to couple turbulent source to far-field observer
  - Important to capture beneficial noise refraction
- Objective
  - Create and validate analytic approximations for twin jets, fluid shield, etc.
- Outcome
  - Initial results encouraging, illustrative
  - Validation in process



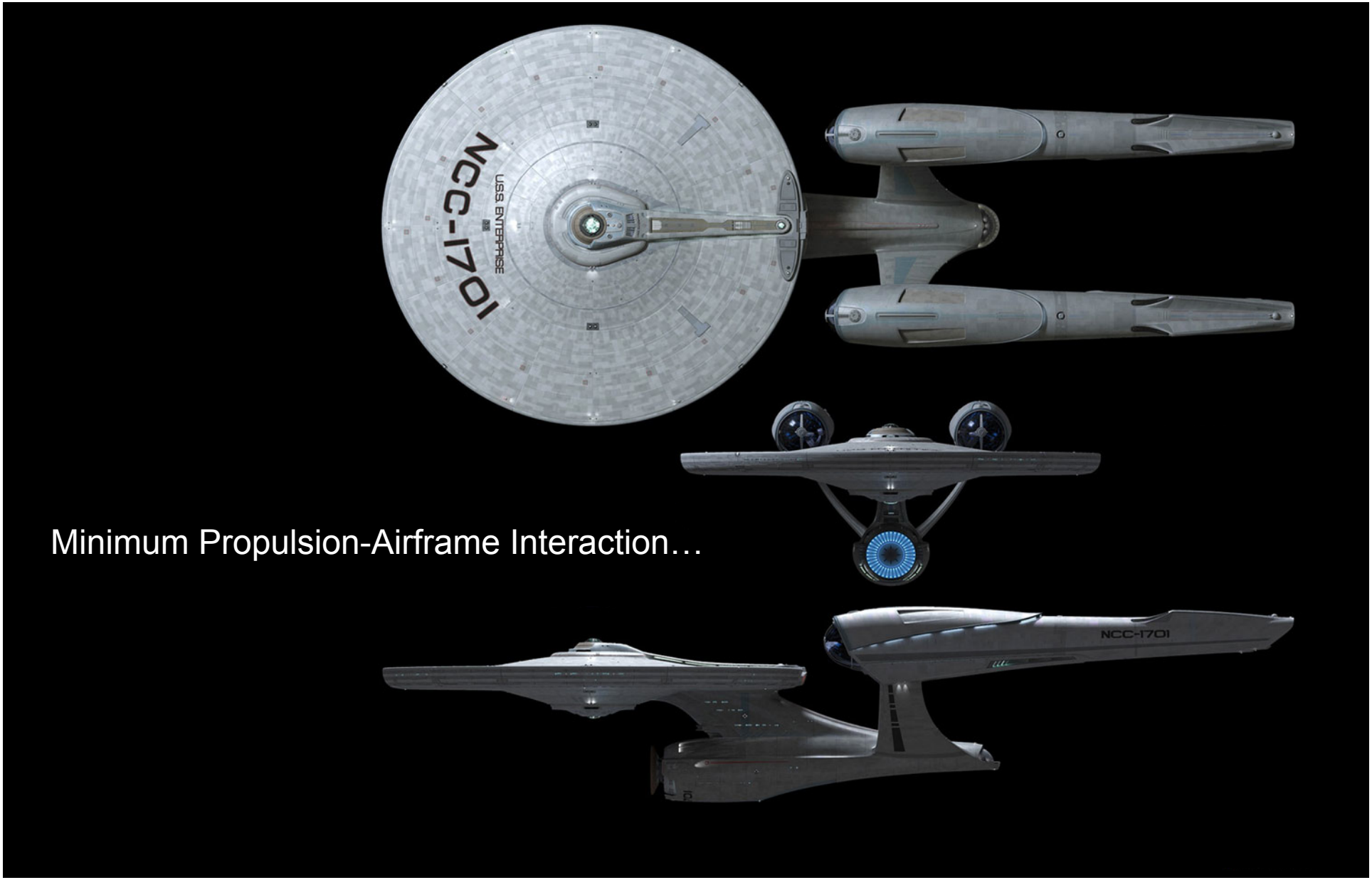
Twin Jet Test Rig, AAPL



15:40 Thursday—Stew Leib



Including Surfaces in Propulsion Noise



Minimum Propulsion-Airframe Interaction…

Recent Publications

- Clem, M. M., Zaman, K.B.M.Q. and Fagan, A.F., "Background oriented schlieren applied to study shock spacing in a screeching circular jet", AIAA Paper 2012-0403, January 2012.
- Zaman, K.B.M.Q., "Effect of nozzle exit conditions on subsonic jet noise", AIAA Paper 2011-2704, June 2011.
- Zaman, K.B.M.Q., Clem, M. M. and Fagan, A.F., "Noise from a jet discharging into a duct and its suppression", AIAA Paper 2012-0007, January 2012.
- Zaman, K.B.M.Q., "Flow field surveys for various rectangular nozzles", AIAA Paper 2012-0069, January 2012.
- Bozak, R., Henderson, B., "Aeroacoustic Experiments with Twin Jets," AIAA Paper 2011-2790, June 2011.
- Miller, S. A. E. and Morris, P. J., "The Prediction of Broadband Shock-Associated Noise Including Propagation Effects," AIAA-2011-2923, June 2011.
- Miller, S. A. E. and Veltin, J., "Experimental and Numerical Investigation of Flow Properties of Supersonic Helium-Air Jets," AIAA Journal, Vol. 29. No 1, pp. 235-246, 2011.
- Nichols, J, Ham, F., Lele, S. & Bridges, J., "Aeroacoustics of a supersonic rectangular jet: Experiments and LES predictions," AIAA-2012-678, January 2012.
- Bridges, J. & Wernet, M.P., "PIV Measurements of Supersonic Internally-Mixed Dual-Stream Jets," AIAA Paper 2011-2786, June 2011.
- Bridges, J. & Wernet, M.P., "Validating LES for Jet Aeroacoustics," Journal of Power and Propulsion, Vol. 28. No 2, March 2012.
- Bridges, J. & Wernet, M.P. "The NASA Subsonic Jet Particle Image Velocimetry (PIV) Dataset," NASA/TM—2011-216807, Nov 2011.
- Henderson, B.S. & Wernet, M.P., "A PIV Study of Slotted Air Injection for Jet Noise Reduction," AIAA Paper 2011-2786, June 2011.
- Frate, F., "Supersonic Nozzle Design for Low-Noise/High-Thrust at Takeoff," SC11 International Conference for High Performance Computing, Networking, Storage and Analysis", Nov. 2011.
- Fagan, A.F., Clem, M.M., Elam, K.A., "Improvement in Rayleigh Scattering Measurement Accuracy," AIAA-2012-1060, January 2012.
- Afsar, M.Z., Goldstein, M.E., Fagan, A., "Enthalpy-Flux/Momentum-Flux Coupling in the Acoustic Spectrum of Heated Jets," AIAA Journal, vol. 49, No. 11, pp. 2522-2531, 2011.
- Leib, S.J. and Goldstein, M.E., 'Hybrid Source Model for Predicting High-Speed Jet Noise,' AIAA Journal, Vol. 49, No. 7, pp. 1324,1355, 2011.

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